

REPLY TO
"COMMENT ON 'MODELING OF CONVECTIVE-STRATIFORM
PRECIPITATION PROCESSES:
SENSITIVITY TO PARTITIONING METHODS'" BY MATTHIAS STEINER

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1. Introduction

We would like to thank Dr. Steiner for his comments on our recent paper, Lang et al. (2003), that compares a variety of convective-stratiform separation techniques within the framework of a cloud-resolving model. Steiner expresses some concerns about the following aspects of the paper: (1) the use of different ice microphysical schemes for the two different cases that were

presented; (2) the lack of an objective basis for evaluating the algorithms which he feels could in fact come from the model microphysical and dynamical data; and (3) that this could lead to "inappropriate mixing of observations and model results." Each of these issues will be addressed in turn along with some minor points.

Convective-stratiform separation serves a variety of very useful purposes that have already been mentioned and is well used as is evidenced by the large number of separation techniques that have been put forth (see Lang et al. 2003 and Steiner's Comment for numerous examples). However, as Steiner himself points out, the distinction between the two regions is not always sharp which leads to a non-uniformity in results. One of the primary objectives of Lang et al. (2003) was in fact to address this issue of how similar or dissimilar the results can be when applied to the same data set. Steiner's primary point is that the various separation techniques although compared were not objectively evaluated to assess their relative performance and that an evaluation could be done using the model's own microphysical data, mainly the hail and graupel contents. Although hail and graupel contents should indeed be an indicator of convection, issues with ice microphysical parameterization and the transition zone, the region where convective elements decay and blend in with the stratiform region, tend to degrade such a would-be benchmark.

2. Microphysical Issues.

First, the cases that were presented are from two distinctly different environments: midlatitude and tropical. For this reason, two different ice microphysical parameterizations were used that best represented each environment. The Lin et al. (1983) ice parameterization was used in the midlatitude PRESTORM simulation because this type of summertime continental environment is more conducive to strong updrafts resulting in the generation of higher density frozen drops that lead to hail. In contrast, the Rutledge and Hobbs (1984) ice parameterization was used in the TOGA COARE simulation as updrafts are typically weaker in a tropical, oceanic environment, and therefore lower density graupel is more representative. McCumber et al. (1991) reported that graupel with its lower terminal velocity was more optimal in such a tropical setting. In the future, more advanced ice microphysical schemes such as a 4-class ice scheme (e.g., Ferrier 1994) or spectral-bin microphysics (e.g., Khain et al. 1999) could be employed to mitigate the effect of having to pre-select the third species of ice.

Steiner's biggest concern is the lack of an objective basis for evaluating the various algorithms which he feels could come from the model results in using the presence of graupel or hail as an indicator of convective processes. Although, the presence of graupel or hail should be an indication of convective processes, there are two issues that limit this as an objective benchmark. The first issue is really a limitation in the current application of the model microphysics. Figure 1a shows a vertical cross section of hail content for the midlatitude PRESTORM case at 720 minutes into the simulation. There are tiny amounts of hail all throughout the anvil which is unrealistic. Overlaid on the hail field is a solid line showing the cumulative hail distribution going from left to right (i.e., from the rear of the anvil toward the convective leading edge). Although the amounts in the anvil are small, they add up to 13% of the total hail content by grid column 200 near the edge of the more

substantial hail contents. So categorizing this hail as stratiform is not really an error by the separation schemes. Similarly, for the TOGA COARE case shown in Figure 1b, 7% of the graupel is contained before grid column 130. The reason for the existence of these tiny hail and graupel contents well into the anvil is likely related to the fact that the only real sink is eventual melting

via sedimentation below the freezing level. Rutledge and Hobbs (1984) do not allow for graupel sublimation in their scheme. And, although Lin et al. (1983) do allow for hail sublimation, it is not a major effect as the anvil hail is embedded in cloud. The autoconversion of snow can produce small amounts of hail or graupel in the anvil. Also, hail or graupel can be advected rearward in the form of convective debris. Using a fixed intercept to approximate their distribution means the assumed mean diameter and consequently the fall velocities are relatively small. This allows the tiny hail or graupel amounts to remain suspended longer in the anvil as well. The fallspeed issue might be partly addressed by a two-moment parameterization scheme. However, in a one-moment scheme as was used in the Lang et al. (2003) study, hail or graupel could be transferred to the snow field when the amounts become sufficiently small and there is no active growth via freezing. The autoconversion of snow could also be limited, especially in the stratiform region, or it should perhaps be eliminated entirely. Large aggregates should not necessarily become small high density hail particles. Indeed, this is an area for potential model improvement.

The second issue relates to the ambiguity in deciding how best to classify the so-called transition region if only 2 categories are allowed: convective and stratiform. The TOGA COARE graupel field in Figure 1b provides a good example. There are three apparent cells, one that is actively growing at the leading edge and two older decaying cells rearward. The oldest cell, farthest to the left, contains 48% of the graupel at this time (between grid columns 130 and 180). Even Steiner's method classifies it as stratiform. Yet, the current remaining updrafts in this cell are only 1 m/s and occur only above the freezing level and

cover a very limited area. Tracing backwards, the last 2 m/s updraft in this cell was 45 minutes prior; only 1 m/s updrafts persisted above the freezing level since that time. Furthermore, the actual leading edge cell which has the strongest updrafts of over 5 m/s only contains just over 1% of the graupel content. It isn't until the updrafts penetrate the freezing level that significant amounts of graupel are produced as seen by the middle cell. Thus the higher graupel amounts are not associated with the most vigorous leading edge convection but rather the "transitioning" cells. These cells are in fact likely to have convective strength updrafts but only above the freezing level which leaves it open to interpretation as to how they should be classified. So for these reasons, the graupel content does not provide an answer for objectively evaluating the various separation schemes.

3. Other Issues.

Steiner makes note of some other concerns with regard to the Lang et al. (2003) study. One is the modifications to the published algorithms. While it may not be optimal to modify the published specifications for the various algorithms, the intent was to reduce differences in performance attributed to differences in the exact value of a specific threshold (e.g., using a 20 instead of a 25 mm/hr surface rainrate threshold for convective rain). With regard to model grid resolution, resolutions will continue to come down as computing power continues to increase. This is an important concern as has been pointed out that separation algorithms are sensitive to resolution (e.g., Steiner et al. 1995). Either the algorithms will have to be adjusted, or model data will have to be smoothed to match the intended resolution of the algorithms. However, in Lang et al. (2003), the intent was to present the cases at model resolutions that have been typically applied and not to do a sensitivity study on the effects of resolution. Finally, in comparing the model results with independent observations, Steiner feels that emphasizing this comparison may be misleading as the model does not compare well with the observed precipitation systems. The Lang et al. (2003) study is very clear

about what the observed stratiform rain values were for these two systems and where those estimates came from. It is important to know what was actually observed. The study is also very straightforward about a potential bias (e.g., Sui et al. 1998) towards heavier rainfall rates in the model-simulated rainfall histogram which could effect the algorithm results, and the conclusions clearly state this.

4. Summary

Despite the obvious notion that the presence of hail or graupel is a good indication of convection, the model results show this does not provide an objective benchmark partly due to the unrealistic presence of small amounts of hail or graupel throughout the anvil in the model but mainly because of the significant amounts of hail or graupel, especially in the tropical TOGA COARE simulation, in the transition zone. Without use of a "transition" category, it is open to debate as how this region should best be defined, as stratiform or as convective. So, the presence of significant hail or graupel contents in this zone significantly degrades its use as an objective benchmark for convection.

The separation algorithm comparison was done in the context of a cloud-resolving model. These models are widely used and serve a variety of purposes especially with regard to retrieving information that cannot be directly measured by providing synthetic data sets that are consistent and complete. Separation algorithms are regularly applied in these models. However, as with any modeling system, these types of models are constantly being improved to overcome any known deficiencies and make them more accurate representations of observed systems. The presence of hail and graupel in the anvil and the bias towards heavy rainfall rates are two such examples of areas that need improvement. Since, both of these can effect the perceived performance of the separation algorithms, the Lang et al. (2003) study did not want to overstate the relative performance of any specific algorithms.

In fact, being able to use the same separation algorithm on the observed system and in the model, provides yet another means of verifying the model. Lang et al.'s (2003) comparison with Johnson and Hamilton (1988) for the PRE-STORM case provides such an example.

And finally, Steiner recommends using the model output to simulate infrared and microwave signatures to test satellite-based techniques. This can certainly be done. In fact, Prasad et al. (1995) used 3D GCE model output to simulate infrared and microwave signatures, and Olson et al. (1996, 1999) regularly use simulated microwave brightness temperatures from the 3D GCE model cloud fields as part of their latent heating retrieval algorithm. Still this is an area that is actively being pursued as statistical analyses of those simulated signatures can be compared with comparable observed statistics as yet another means of validating the model. Ultimately, as the model is improved via rigorous comparisons with observations, the separation techniques will either converge to a more common solution or the better or best technique(s) will emerge. Again we would like to thank Dr. Steiner for his insightful comments and for bringing forward some important issues.

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FIGURE CAPTIONS

Figure 1 Vertical cross section after 720 minutes of integration of model-simulated (a) hail content for the PRESTORM case and (b) graupel content for the TOGA COARE case. Convective regions for each of the separation techniques listed in Lang et al. (2003) are overlaid in solid black lines. Traces of the cumulative hail/graupel distribution from left to right are also overlaid (domain top = 100 %).

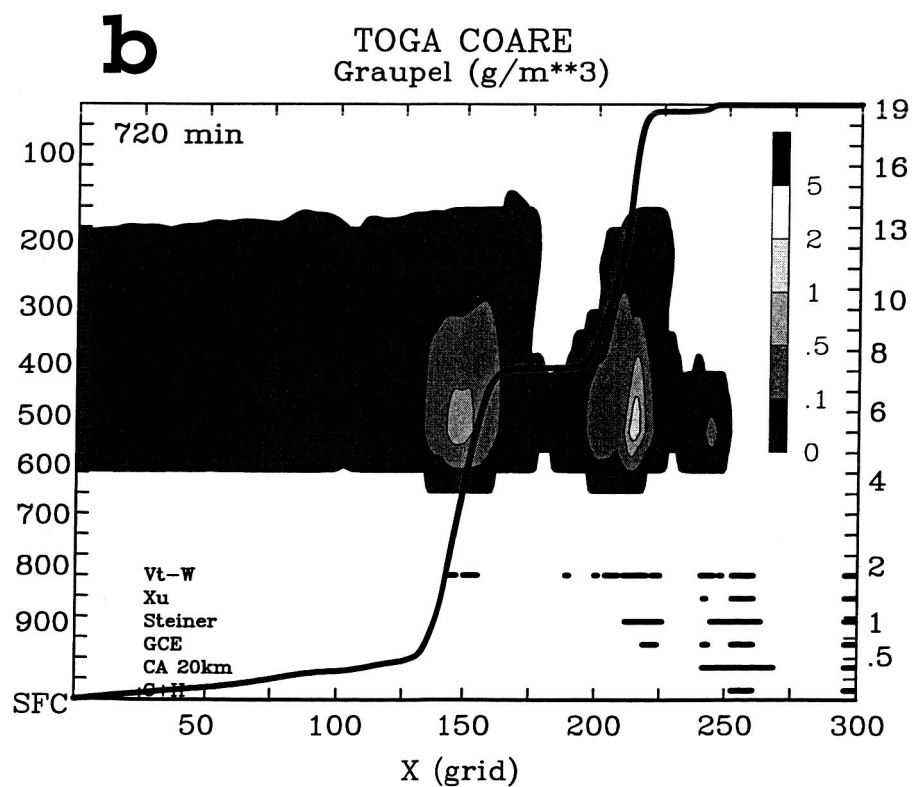
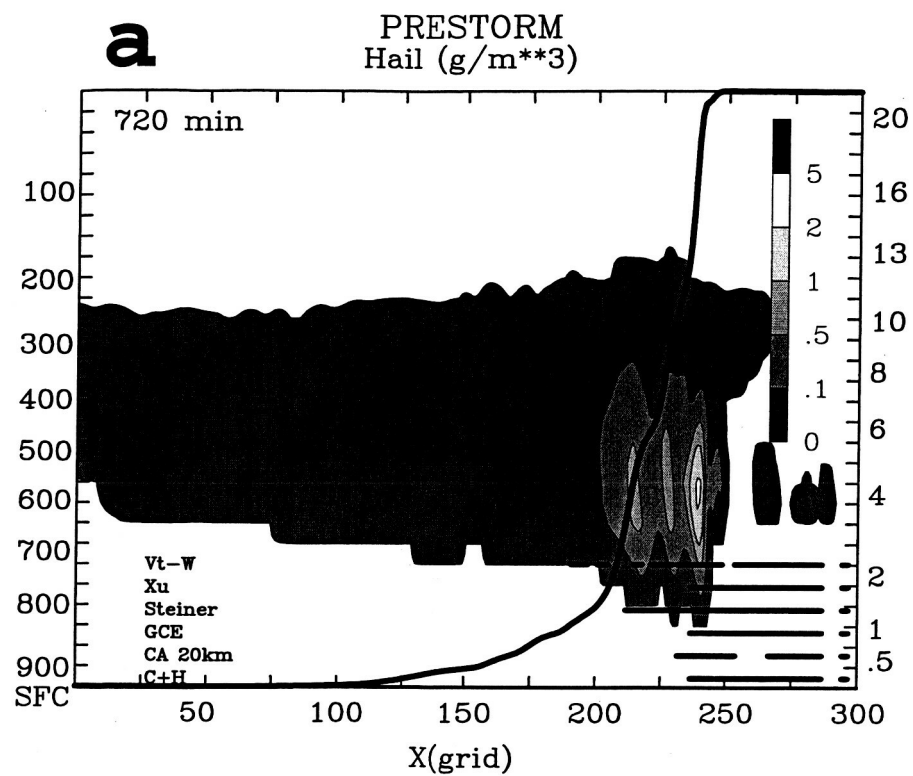


Figure 1